AN ECOLOGICAL SURVEY OF THE HOT SPRINGS AREA, HURUNUI RIVER, CANTERBURY, NEW ZEALAND

J.D. STARK, R.E. FORDYCE, and M.J. WINTERBOURN

Department of Zoology, University of Canterbury, Christchurch, New Zealand

ABSTRACT

The Hurunui River hot springs (172°02'E, 42°41'S) occur in Torlesse Supergroup rocks near the Hope Fault, South Island, New Zealand. A distribution map of the 25 hot springs in the South Island is given. The Hurunui springs open through 12 vents between 630 m and 660 m altitude, and the water has a temperature of 21°C to 54°C.

Beeches (*Nothofagus* spp.) form the dominant vegetation around the springs, and 13 or more bird species occur there.

Spring waters were alkaline, and analyses show that levels of K^+, Ca^{++}, Mg^{++}, Cl^-, and Si^{4+} are the lowest recorded in thermal spring waters in New Zealand. The dominant cation was Na^+, and anion HCO_3^-.

Species of the algae *Mastigocladus, Phormidium, Oscillatoria, Synechococcus, Lyngbya,* and *Calothrix* were found. Five species of Diptera, one coleopteran, and two species of semi-aquatic mites were collected from the algae and detritus in the outflow channel. Chironomid larvae were dominant below 41°C. The known temperature range of Ephydridae and Stratiomyidae in New Zealand is extended by the discovery of *Scatella nitidifrons* pupae and an unidentified Stratiomyinae larvae at 47°C. Dipteran larvae also predominated in clumps of moss (*Campylium polygamum*) found beside flowing water in the lower region of the channel, although the moss fauna was more diverse than the fauna of the spring channel.

The results of this study are compared with those of similar studies in New Zealand and overseas.

INTRODUCTION

Extensive biological surveys of the biota living in thermal spring outflow channels in the North Island of New Zealand have been made recently by Winterbourn (1968) and Brock and Brock (1971). In contrast, only two brief biological studies of South Island warm springs have been made, perhaps because most springs are located in relatively inaccessible valleys in the Southern Alps (Fig. 1). In the first of these studies, Smith (1969) examined the distribution of the macrofauna in a stream which is warmed by water from a thermal pool at Hanmer Springs, North Canterbury. The second study was an ecological investigation of the Copland Springs, near Fox Glacier, Westland, made by Winterbourn (1973). In the latter paper observations made on the flora and fauna at four other South Island warm springs also were recorded.

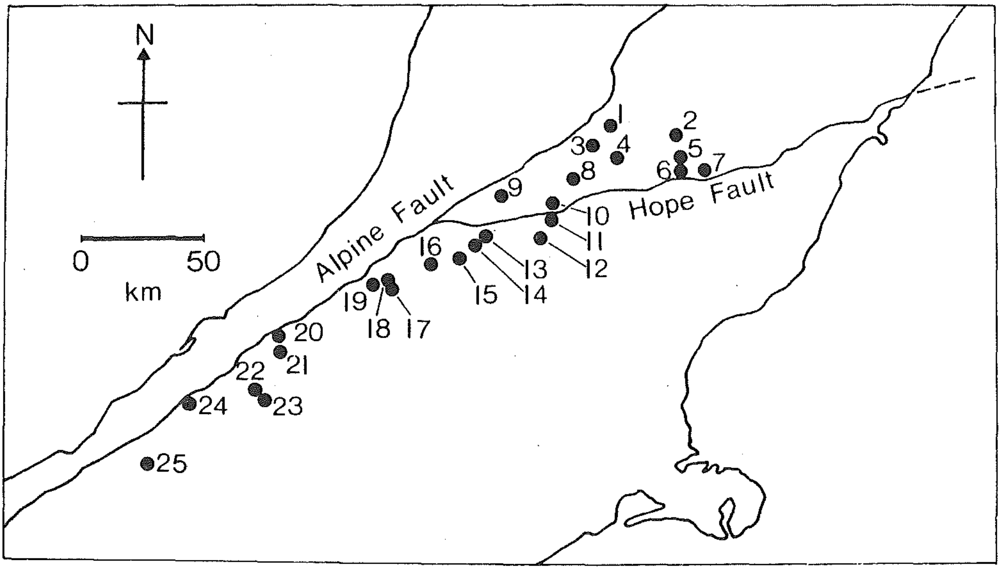

Fig. 1. Hot springs of the South Island, New Zealand. Only springs in rocks of the Torlesse Supergroup are shown. Localities are as follows:

1. Maruia River
2. Cow Stream, Waiau River
3. Lake Christabel, Grey River
4. Nina River
5. Grantham River (grid reference S54/064795 or 172°40'00"E, 42°31'10"S; found by P.J. Ryan and R.E. Fordyce, November 1973)
6. Grantham River
7. Hanmer Springs
8. Hot Spring Creek, Hope River (see Fig. 2)
9. Haupiri River
10. MacKenzie Stream (Fig. 2)
11. Hurunui River (this study, see Fig. 2)
12. Poulter River, East branch
13. Otehake River
14. Deception River
15. Otira River
16. Taipo River
17. Kokatahi River
18. Kokatahi River
19. Toaroha River
20. Wanganui River
21. Wanganui River (2 vents)
22. Fox River
23. Fox River
24. Franz Josef Glacier
25. Copland River

The purpose of the study reported here was to conduct a brief survey of the biota and physical environment and surrounds of the hot springs, Hurunui River, North Canterbury. The composition and distribution of the biota is related to physical features of the springs, and compared with the results of other studies in New Zealand and overseas.

AN OUTLINE OF SOUTH ISLAND HOT SPRINGS

A map of the hot springs of the South Island, New Zealand, was given by Ellis and Mahon (1964: Fig. 1). They illustrated 18 springs within Torlesse Supergroup rocks, and also showed the positions of the Alpine, Kaikoura, and Wairau faults. The map presented in this paper (Fig. 1) updates that of Ellis and Mahon. It is based on data presented by Bowen 1964, Gregg 1964, Warren 1967, and Gair 1968, and a field survey by R.E. Fordyce and P.J. Ryan, November 1973. This map shows only hot springs in rocks of the Torlesse Supergroup.

The springs illustrated in Fig. 1 occur east of the Alpine Fault in the axial region of the South Island, and along the Hope Fault. No reason for this association is known, and it is uncertain whether spring water is circulating ground water that has been heated at depth, or juvenile water derived from hot rocks at great depth. A brief discussion of this problem was given by Holmes (1965). A recent paper on the Hope Fault (Freund 1971) did not discuss any of the 11 or so hot springs that occur close to the Hope Fault.

HURUNUI RIVER HOT SPRINGS

The hot springs discussed in this paper occur in the upper reaches of the Hurunui River about 9 km west of Lake Sumner, Canterbury (Fig. 2); grid reference S 53/490582 or 172°02'50"E, 42°41'50"S (N.Z.M.S. 1 S 53). The upper Hurunui River lies within Lake Sumner Forest Park, a recreation area administered by the New Zealand Forest Service. Access to the springs is by public road to "Number 2" hut (3.5 km west of Lake Sumner) then by a foot track on the south bank of the Hurunui River. A general description of the forest park was given by Searell (1975).

Two other hot springs occur within the forest park (Fig. 2). These are in the MacKenzie Stream, Hurunui watershed, and Hot Spring Creek, Hope watershed (Gregg 1964, and N.Z.M.S. 1 S 53). These springs were not studied during this investigation.

Twelve vents were discovered for the Hurunui River hot springs (hereafter referred to as the springs or spring area). These vents open into channels which flow roughly northwards toward the Hurunui River (Fig. 3). Only the water from vents S1 and S2 actively flows into the river; water from the other vents drains underground before it reaches river level. The channels from S1 and S2, and S4, S5, and S6 are the largest, and are 5-10 m wide in places. Channels from other vents are small, and that from vents S11 and S12 is silted up. Longitudinal channel profiles vary from flat to slopes of about 30°. Altitudes and temperatures of the vents are given in Table 3.

The spring vents chosen for detailed study were S1 and S2 (Fig. 4). The upper vent, S1, is about 4 m altitude above S2.

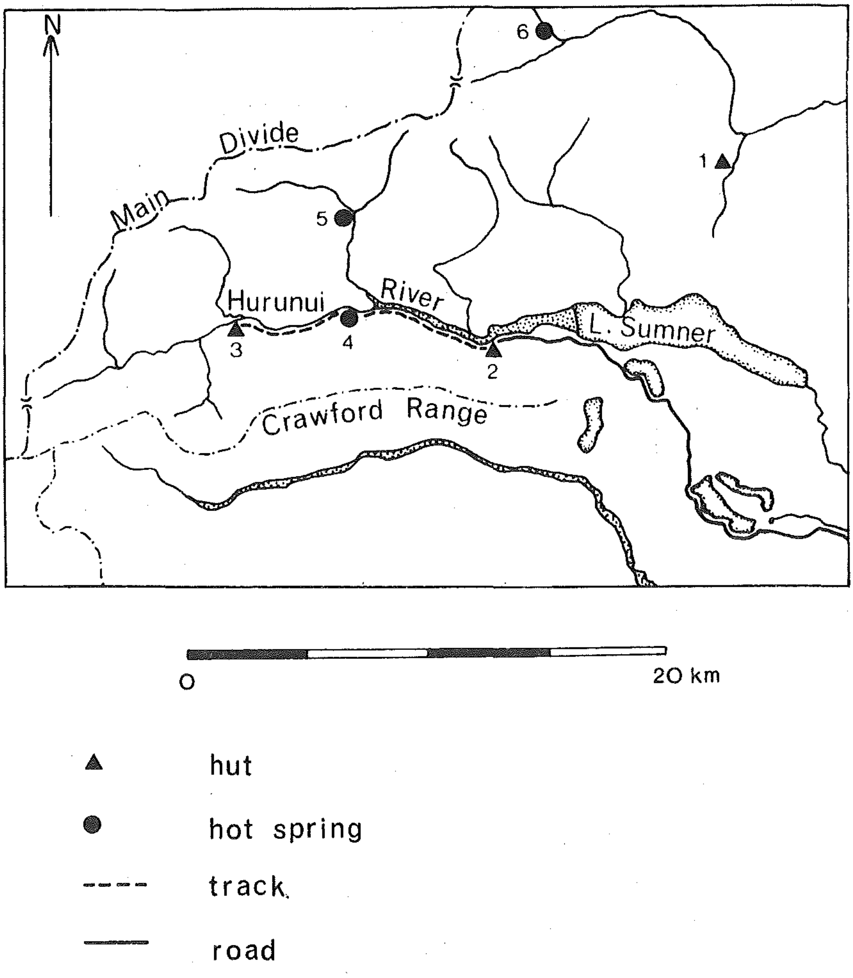

Fig 2. Map of the upper Hurunui River area, Lake Sumner Forest Park, Canterbury. Numbers refer as follows.

1. Hope-Kiwi lodge (hut)
2. Number 2 hut
3. Number 3 hut
4. Hurunui River hot springs (see Fig. 3)
5. MacKenzie Stream hot spring
6. Hot Spring Creek (Hope River) hot spring

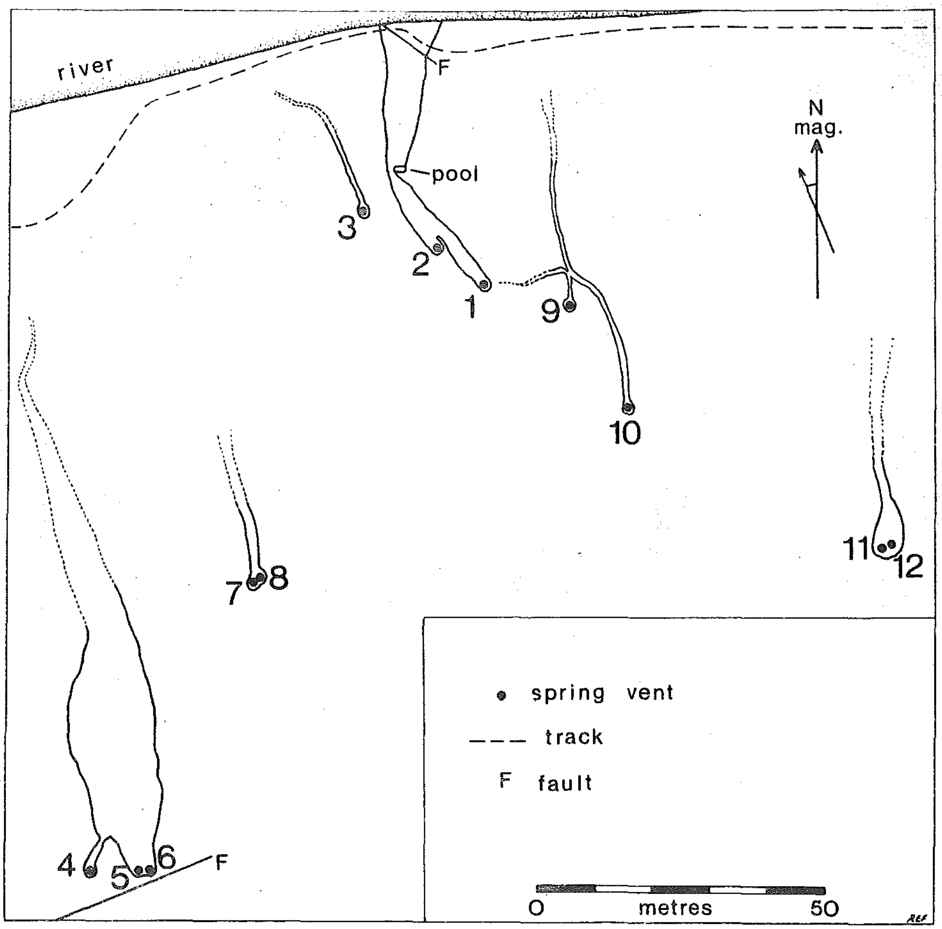

Fig. 3. Detailed map of the 12 vents and channels of the Hurunui River hot springs. All channels flow roughly north. The scale on this map may not be perfectly accurate, as the area was difficult to map.

Numbers, in the text prefixed by S, refer to spring vents.

Effluent from both vents joins just below S2, and runs north-west toward the river. Below a point where the spring channel bends markedly northwards, there is a man-made pool or bath in the rock, of dimensions 1.0 m x 2.0 m x 0.4 m deep. In May 1975, the hot spring effluent flowed into this pool, but in February 1976 litter accumulation had diverted the flow away from the pool. A small, cool-water (15°C) trickle flows into the pool from the east, and another cool-water inflow is present about 2 m below this pool. Below the pool, in its widest section, the channel widens markedly. The effluent flows over only a small part of it, but probably changes its course as detritus modifies the profile of the channel. Towards the river, a track (the foot track from Number 2 to Number 3 hut)

Fig. 4. The spring channel, and vents S1 and S2, from a point about 7 m above the pool. Positions of the vents are indicated by arrows. Vent S1 is in the upper left, and vent S2 in the middle right of the photo. Note the debris in the channel, and the dense vegetation around the channel. The scale in the middle of the photo is 1 m long.

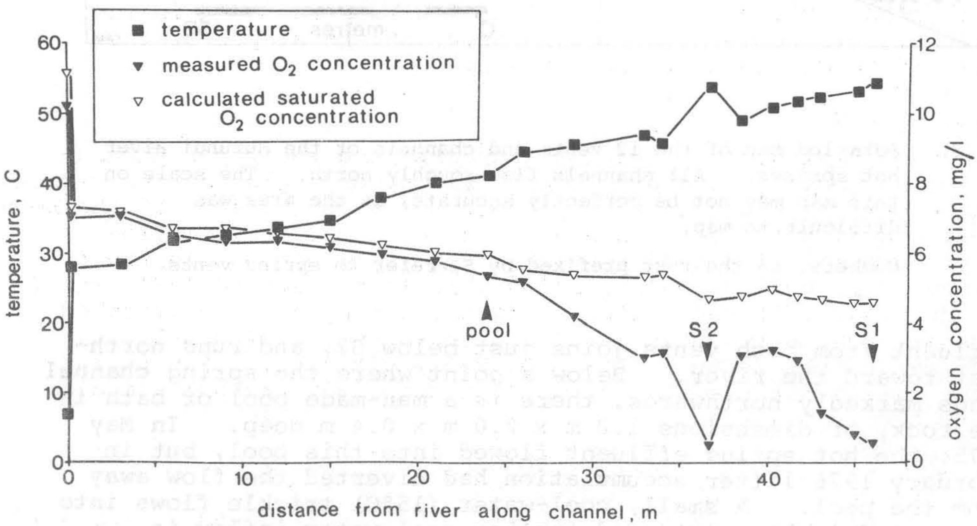

Fig. 5. Temperature and oxygen profiles for the hot spring effluent channel from S1 and S2.

crosses the channel, as does a small fault. The rock of the channel is very shattered here. A few metres below the track is the river.

GEOLOGY OF THE SPRING AREA

ROCK TYPES

The subsurface rocks, and those which form the spring channels, are sandstone and mudstone of the Torlesse Supergroup. These rocks occur throughout the upper Hurunui Valley and much of Canterbury. They were mapped by Gregg (1964) as Mesozoic, perhaps Triassic, "strongly indurated, mostly graded-bedded greywacke and argillite, with beds of basic volcanics with associated sediments".

Samples of the rock collected from around the springs were well-indurated grey unfossiliferous sandstones and mudstones, typical of Torlesse Supergroup rocks. The rocks are shattered in places, and outcrops are difficult to find away from the river. The limited occurrence of good outcrops prevented geological mapping of the area.

Small deposits of alluvium, which contain sand and angular rock fragments, crop out in places in the spring area, and vents S8, S10, S11, and S12 open through this alluvium. The presence of porous subsurface sediments, such as these, which rest on Torlesse Supergroup sandstones, indicates that some spring waters may soak away without reaching the surface. This alluvium occurs only sporadically, and its extent was not determined.

FAULTS

Two faults were discovered in the spring area (see Fig. 3). One recent fault trace, about 5 m high, is present a few metres south of S4, S5, and S6. No other faults were found in the spring area, though fault traces occur on the slopes of the Crawford Range south of the springs.

PHYSIOGRAPHY

The physiography of the spring area and the upper Hurunui Valley has mainly been affected by Pleistocene glaciations, which carved out the U-shaped valley system. Recent traces of the Hope Fault modified the landscape after glaciation. Glaciation affected mostly the region below 1500 m altitude, while fault traces occur both above and below this level (Freund 1971: Map 2). On the Crawford Range south of the springs, glacially-smoothed rock surfaces crop out sporadically on a series of gently sloping benches between about 700-900 m altitude. Fault traces with displacements of up to 5 m (not mapped by Freund) are also found here.

VEGETATION OF THE SPRINGS AREA

The beeches, *Nothofagus fusca, N. menziesii,* and *N. solandri* (red, silver, mountain beeches respectively), form the dominant forest throughout the Hurunui Valley. Generally, red beech is common at low altitude especially on old river terraces, mountain beech on ridgetops and on bush fringes by riverbeds, and silver beech at higher altitudes, particularly near the bushline.

These beeches also form the bush canopy in the spring area. Silver beech is the dominant canopy species near S1 and S2, while mountain and red beech occur here as scattered small trees. The fairly low and open canopy by S1 and S2 is also formed of broadleaf (*Griselinia littoralis*) and celery pine (*Phyllocladus alpinus*), with a few scattered lancewoods (*Pseudopanax crassifolius*). Many of the adult celery pines that once formed part of the canopy are now dead, and both living and dead trees are covered in places with an orange alga, *Trentepholia* sp.

At vents above S1 and S2 (for example, S4, S5, S6), the canopy is higher and more dense. Here, red beech is a dominant canopy species, and marbleleaf (*Carpodetus serratus*) occurs as a subcanopy tree. Parallel to the river, away from the springs, mountain beech becomes the dominant canopy species.

Below the open canopy at S1 and S2, the ground is steep, and is bare of vegetation in places. Visitors to the spring vents appear to have trampled vegetation around the spring channel. Litter is thick and abundant, even in denuded areas. Above the bath (Fig. 3), sedges, tangle-fern (*Gleichenia dicarpa*), bracken (*Pteridium esculentum*) and water fern (*Histiopteris incisa*) are abundant in places, and form the dominant ground cover around the channel (Fig. 4). These species do not occur under the beech canopy; here, juvenile celery pine, mingimingi (*Cyathodes juniperina*), scattered manuka (*Leptospermum scoparium*), abundant coprosmas (*Coprosma foetidissima, C. propinqua, C. crassifolia*), lawyer (*Rubus* sp.). *Pittosporum divaricatum*, and red, silver, and mountain beech occur as small plants generally under 1 m high.

A detailed, quantitative survey of the vegetation of the spring area was not attempted, as none of the investigators had the experience or time to carry this out.

VERTEBRATES OF THE SPRING AREA

BIRDS

A checklist of birds identified in the spring area on 22-25 May 1975, and 15-16 February 1976, is given in Table 1. With the exception of the spur-winged plover, all species listed probably breed in the area. The weather during the May trip was particularly bad, and the February trip was short, so the checklist is considerably smaller than could reasonably be expected for an area such as that around the hot springs. For example, a survey of the birds of the Hurunui River above the hot springs (R.E. Fordyce, D.A. Banks, R.J. Scoones, New Zealand Forest Service, November-December 1974) recorded these species in addition to those listed in Table 1; black shag (*Phalacrocorax carbo*), grey duck (*Anas superciliosa*), blackbacked gull (*Larus dominicanus*), pigeon (*Hemiphaga novaeseelandiae*), kea (*Nestor notabilis*), shining cuckoo (*Chalcites lucidus*), longtailed cuckoo (*Eudynamis taitensis*), morepork (*Ninox novaeseelandiae*), hedge sparrow (*Prunella modularis*), brown creeper (*Finschia novaeseelandiae*), yellowhead (*Mohoua ochrocephala*), thrush (*Turdus philomelos*), tui (*Prosthemadera novaeseelandiae*), yellowhammer (*Emberiza citrinella*), greenfinch (*Carduelis chloris*), and house sparrow (*Passer domesticus*). Any of these species could live in the bush or on the riverbed by the hot springs. There

TABLE 1. BIRDS OF THE HOT SPRINGS AREA AND HURUNUI RIVER. Areas: A = hot springs, B = between hot springs and No. 2 hut.

Name		Area A	Area B
Apteryx haasti (?)	great spotted kiwi	X(1)	
Ardea novaehollandiae	white-faced heron		X
Branta canadensis	Canada goose		X
Tadorna variegata	paradise duck	X	X
Circus approximans	harrier		X
Falco novaeseelandiae	falcon		X
Haematopus ostralegus	South Island pied oystercatcher		X
Lobibyx novaehollandiae	spur-winged plover		X
Charadrius bicinctus	banded dotterel		X(2)
Nestor meridionalis	kaka	X	
Cyanoramphus auriceps	yellow-crowned parakeet	X	
Acanthisitta chloris	rifleman	X	
Anthus novaeseelandiae	pipit	X	
Gerygone igata	grey warbler	X	X
Rhipidura fuliginosa	South Island fantail	X	X
Petroica macrocephala	yellow-breasted tit	X	X
Petroica australis	South Island robin	X	X
Turdus merula	blackbird	X	X
Zosterops lateralis	waxeye		X
Anthornis melanura	bellbird	X	X
Fringilla coelebs	chaffinch		X
Carduelis carduelis	goldfinch	X	X
Acanthis flammea	redpoll		X
Sturnus vulgaris	starling		X
Gymnorhina tibicen	white-backed magpie		X

Footnotes to table.

1. R. Nation (pers.comm.) to R.E. Fordyce. Kiwis were heard in the bush near the springs by R. Nation (October 1974), but were not identified.

2. Banded dotterel were seen only during the summer.

is nothing apparent about the springs area that would make it any more or less suitable as bird habitat than any other region of the Hurunui River, and there was no evidence that birds exploited any features of the spring system.

MAMMALS

No mammals were seen in the springs area during the survey. Mammals known to occur in the Hurunui River area above and below the springs include red deer (*Cervus elaphus*), chamois (*Rupicapra rupicapra*), opossum (*Trichosurus vulpecula*), rabbit (*Oryctolagus cuniculus*), hare (*Lepus europaeus*), mouse (*Mus musculus*), and rat (*Rattus* sp.) (field surveys, R.E. Fordyce). Faeces of red deer and opossum indicated that these species occur around the springs, and the other mammals known from the valley may also occur there occasionally. Mustelids (species unknown, see Marshall 1963) occur in Lake Sumner Forest Park, but it is not known if they frequent the springs area.

ECOLOGY OF THE SPRINGS: METHODS AND PROCEDURES

Fieldwork was carried out on 23-25 May 1975 and 15 February 1976. The spring channel chosen for detailed study (that of S1 and S2) was the second largest and most accessible of six discrete channels in the area (Figs 3 & 4). Unless otherwise stated, this is the channel referred to hereafter.

In May 1975, water temperature and oxygen concentration were measured at intervals from vents S1 and S2 to the Hurunui River with a Y.S.I. Model 54 oxygen and temperature meter. Maximum-minimum thermometers were placed in vents S1 and S2 for 2 days, and supplementary temperature measurements were made in the outflow channel with a mercury thermometer. The pH of water from the vents was measured with B.D.H. universal indicator. Water samples for detailed chemical analysis were taken from 6 vents, including S1 and S2.

The invertebrate fauna was sampled at 10 sites along the channel by washing approximately 0.05 m^2 portions of algal mat and detritus into a plankton net. Samples were preserved with 4% formalin.

Core samples used for algal identification were taken from 16 sites and preserved in formalin. Two samples of a semi-aquatic moss, *Campylium polygamum*, which grew 50-100 mm above the water in the lower section of the channel, were also taken. Temperatures within the clumps of damp moss were not measured but water temperatures at the two sites where the samples were taken were 32.5°C and 33.5°C respectively. Adult Diptera were collected with a sweep net.

In February 1976, water temperatures in all 12 vents were measured and the location of each vent mapped (Fig. 3). Samples of algal mat were taken for identification at 6 temperatures (26°C, 39°C, 41°C, 50°C, 52°C, and 54°C) along the channel. These were not preserved. The invertebrate fauna was sampled at 5 sites (at 26°C, 28°C, 29°C, 37°C, and 46°C) and the samples preserved in 70% alcohol. As in May 1975, adult Diptera were collected with a sweep net.

In the laboratory, moss and algal mat samples were washed through a series of sieves (1 676, 850, 300 and 180 μm mesh) to separate animals from plant and detrital material. Invertebrates were sorted from samples under a stereoscopic dissecting microscope at magnifications from 12.5X to 80X, identified and counted. Microscope slides of algae were prepared and identified at magnifications ranging from 100X to 1000X. A conservative approach to the identification of blue-green algae is taken in this paper as recommended by Castenholz (1969) and the conventional definitions of genera are followed. This facilitates the comparison of our findings with those made in most other studies of thermophilic algae.

ECOLOGY OF THE SPRINGS: RESULTS

PHYSICAL AND CHEMICAL FACTORS

Results of chemical analyses made on water samples taken in May 1975 (vents S1, S2, S3, S5, S9 and S10) and February 1976 (vents S1 and S2) are shown in Table 2. Water temperatures in the vents ranged from 28.0°C to 54.5°C in May and 21 to 55.5°C in February (Table 3). The springs were strongly alkaline (pH 8.0-9.2), and Na^+ was the main cation and HCO_3^- the predominant anion. Sulphate levels were low and only trace amounts of Cl^- were present. Levels of Mg^{++}, Ca^{++} and K^+ were extremely low. However, in February 1976 the concentrations of K^+, Ca^{++}, Mg^{++}, Cl^- and NO_3^- were significantly higher than in May 1975, while the concentrations of SO_4^{--} and total solids had fallen.

Water temperatures and dissolved oxygen concentrations measured at intervals along the channel leading from vents S1 and S2 on 23 May 1975 are shown in Fig. 5. Water temperature fell from 54.5°C to 28°C in 46 m below S1. A slight increase in water temperature was caused by the inflow of water from S2, 9.3 m below S1. Maximum-minimum thermometer readings in vents S1 and S2 showed no fluctuations over a 2-day period. Water flowing from the vents was poorly oxygenated (10-12% saturation) but 95% saturation was attained where the outflow channel became steeper and turbulence increased about 20 m from S1.

THE ALGAL MAT

Samples of blue-green algal mat were collected from the spring outflow channels in May 1975 and February 1976. A diverse algal community was found. At the highest temperatures (53-54°C) the firm, dark green mat was composed of intermingling filaments of *Phormidium* sp., *Lyngbya* sp. and *Mastigocladus laminosus*. The *Phormidium* and *Lyngbya* species had trichome diameters of 3 μm and the latter possessed colourless, striated sheaths 3-4 μm thick. Around vent S2 (54°C) the mat contained many short filaments of *Oscillatoria geminata*, resembling the variety *tenella* forma *minor* described by Kullberg (1971). Flocculent growths of bright blue-green algae growing on twigs and dead beech leaves at 53-54°C were composed of a 3 μm diameter species of *Oscillatoria*. In May, the mat in the temperature range 48-52°C was composed principally of *Lyngbya* filaments arranged in parallel to form a dark blue-green, leathery substrate up to 7 mm thick in places. Mixed with *Lyngbya* was a narrow (<1 μm diameter) *Phormidium* species which dominated the mat community at 46°C. Lower down the channel (35-40°C) slightly broader (1-2 μm) filaments of *Phormidium* were the dominant organisms in a dark green, somewhat furry mat. From

TABLE 2. RESULTS OF CHEMICAL ANALYSES OF WATER SAMPLES TAKEN FROM SIX SPRINGS ON 23 MAY 1975 AND FROM TWO SPRINGS ON 15 FEBRUARY 1976. Springs are numbered as in Fig. 3.

	May 1975						Feb. 1976	
Springs	S1	S2	S3	S5	S9	S10	S1	S2
pH	9.0	9.0	8.7	9.2	8.0	9.0	9.1(1)	9.1(1)
Sodium	93	93	68	93	76	92	95	96
Potassium	0.9	0.8	0.6	0.8	1.0	1.0	1.4	1.4
Calcium	1.1	1.2	2.3	1.2	3.2	1.5	5	5
Magnesium	0.02	0.03	0.11	0.03	0.34	0.13	0.6	0.8
Chloride	<1	1	<1	2	0.5	<1	3	3
Sulphate	12	12	16	18	23	17	5	7
Bicarbonate alkalinity (as HCO_3^-)	146	156	134	102	160	128	183	170
Alkalinity (to pH 8.3 as CO_3^{2-})	22	19	6	36	0	26	28	26
Reactive silica (as SiO_2)	60	60	60	60	60	60	60	60
Total solids	316	324	240	314	275	388	296	291
Nitrate nitrogen	0.4	0.4	0.04	0.06	1.6	0.6	0.9	0.8
Nitrite nitrogen	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ammoniacal nitrogen	0.36	0.37	0.10	0.14	0.49	0.23	0.30	0.44
Albuminoid nitrogen	0.006	0.006	0.016	<0.005	0.3	0.09	0.01	<0.005
Permanganate value (100°C, 30 min.)	3.6	3.0	0.1	0.6	4.4	2.6	4.9	4.4
Iron	<0.04	<0.04	0.06	0.05	0.20	0.21	0.04	0.20
Manganese	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-
Total hardness (as $CaCo_3$)	-	-	-	-	-	-	15	16
Free carbon dioxide (as CO_2) (calc)	-	-	-	-	-	-	Nil	Nil

1. Field pH = 10

TABLE 3. VENT TEMPERATURES AND ALTITUDES.

Vent	Altitude (m)	Temperature May 1975	Temperature February 1976
S1	639	54.5	54
S2	635	54	53.5
S3	630	46	46
S4	690	28	38
S5	690	54	55.5
S6	690	42	53
S7	660	- (1)	42
S8	660	- (1)	24
S9	642	46	42.5
S10	645	53	53
S11	660	- (1)	23
S12	660	- (1)	21

1. These springs were not identified as thermal springs in May, as they were cool as a result of groundwater influence. Hence their temperatures were not measured.

TABLE 4. DISTRIBUTION OF AQUATIC INSECTA AND ACARI IN THE OUTFLOW CHANNEL FROM SPRING S1 IN MAY 1975. Abundance scale: F = few (1-10/0.1 m^2); C = common (11-30/0.1 m^2); A = abundant (>30/0.1 m^2).

Taxa	Life history stages	Water temperature (°C)									
		28.5	32.0	32.5	35.0	38.0	40.0	41.0	45.0	46.5	47.0
DIPTERA											
Ephydridae											
Scatella nitidifrons	larvae			F	C		C		F		F
	pupae	F	F		C	C	F	C	F	F	F
Stratiomyidae											
Stratiomyinae	larvae	F						C			F
Chironomidae											
Chironominae - Tanytarsini	larvae	A	A	A	A	C	F	F			
	pupae	C	F	F	F	F					
Tanypodinae	larvae	C	F	F	F						
Orthocladiinae	larvae	C	F	F		F		F			
COLEOPTERA											
Dytiscidae											
Liodessus deflectus	larvae	C			F						
	adults	F		F							
ACARI											
Hydrozetidae											
Hydrozetes lemnae	adults	A	F	A				C			
Malaconothridae											
Trimalaconothrus novus	adults & nymphs							F			

15°C to 38°C *Calothrix* sp. was the main component of a tough, closely encrusting mat with an almost black, nodular upper surface.

In February, the algal community showed the same species zonation as in May with one main exception: within the temperature range 48°C-50°C, a thin, bright-pink layer of actively dividing unicellular cyanophytes belonging to the genus *Synechococcus* was present on top of a thick, fibrous base of empty *Lyngbya* sheaths. The algal cells contained prominent granules and resembled the cosmopolitan species *Synechococcus minervae* which contains the red pigment phycoerythrin (Castenholz 1973). A few cells of a second *Synechococcus* species were seen in the *Phormidium*-dominated mat at 41°C, and 4 µm diameter filaments of *Oscillatoria* coexisted with *Phormidium* at 39°C and with *Calothrix* at 27°C.

AQUATIC FAUNA

Five species of Diptera, one coleopteran and two species of semi-aquatic mites were collected from the algal mat and among plant debris in the outflow channel in May 1975 (Table 4). All eight species were found at 28.5°C, the minimum water temperature in the channel; no living animals were found above 47°C. In February 1976, seven of these species were found, all occupying similar temperature ranges as in May. Midge larvae of the subfamily Orthocladiinae were absent in February but no additional species were found.

Above 41°C, the only insects found were larvae and pupae of an ephydrid fly *Scatella nitidifrons* and the larvae of an unidentified species of Stratiomyinae. Adults of *Scatella nitidifrons* were seen feeding on the algal mat at up to 40°C. *Ephydrella thermarum*, the most common ephydrid in North Island thermal waters up to 47°C (Winterbourn 1968, Dumbleton 1969) was not found.

Chironomid larvae were the dominant invertebrates at all sampling points below 41°C. Three species belonging to the subfamilies Tanypodinae, Orthocladiinae and Chironominae-Tanytarsini were present but none could be positively identified. The species of Tanytarsini (keying to the genus *Micropsectra* in Mason (1968)) was most abundant. Larval and pupal Tanytarsini occupied light, sandy tubes on the upper surface of the algal mat and were particularly prominent at lower temperatures where the mat was very dark and composed principally of *Calothrix*. Adult Tanytarsini were collected from exposed algal mat and from rocks adjacent to the channel

Larvae and adults of the dytiscid *Liodessus deflectus* were the only beetles found. This species has not been recorded previously from thermal waters, although dytiscids identified as *Liodessus plicatus* have been recorded in the North and South Islands by Winterbourn (1973) and Forsyth and McColl (1974).

Two species of semi-aquatic mite (Acari, Cryptostigmata), *Hydrozetes lemnae* and *Trimalaconothrus novus* were collected from the outflow channel. Large numbers of adult and nymphal *Trimalaconothrus novus* were found at 28.5°C, and smaller numbers at 32°C, 32.5°C, and 41°C. Cadavers of *Hydrozetes lemnae* were taken at 28.5°C and 32.5°C and living, adult mites at 41°C. *Hydrozetes lemnae* is widespread in New Zealand but *Trimalaconothrus* *novus* was known previously only from localities near Queenstown and Dargaville (G.W. Ramsay, pers. comm.).

In addition to the two species of aquatic mites, adults and cadavers of 20 non-aquatic species belonging to 13 families of Cryptostigmata and Mesostigmata were taken from the outflow channel. It is possible that they had fallen into the water from surrounding vegetation and litter.

MOSS FAUNA

In the lower section of the outflow channel, small clumps of the moss *Campylium polygamum* were growing on the rock substrate 50-100 mm above the water. The estimated temperature within the moss where the samples were taken was 20°C-28°C. The invertebrate fauna present was more diverse than that inhabiting the algal mat, and contained representatives of several groups which typically are found in "normal" fresh waters.

As in samples taken from the algal mat, dipteran larvae predominated. The same species of Chironomidae, Ephydridae and Stratiomyidae as occurred in the algal mat inhabited the clumps of moss, along with a species of Ceratopogonidae and two tipulids, *Paralimnophila skusei* and *Aphrophila* sp. Other animals collected were larval Helodidae (Coleoptera), larval Hydroptilidae (Trichoptera) including *Oxyethira albiceps*, an ostracod *Darwinula* sp., a species of Copepoda-Harpacticoida, the hydrobiid gastropod *Potamopyrgus antipodarum* and several collembolans, spiders and mites.

DISCUSSION

The Hurunui springs are located in a non-volcanic region of New Zealand, and chemically resemble the "meteoric, low-salinity thermal waters category" of Castenholz (1969). In springs of this type, temperatures are often lower than those of volcanic springs, nitrogen is usually the major gas, sodium or calcium is the dominant cation, and chloride levels are usually low compared with those of bicarbonate or sulphate. The chemical characteristics of the Hurunui spring waters are notably different from those of other New Zealand thermal springs (cf. Castenholz 1969, Ellis and Mahon 1964, Winterbourn 1973, and Chemistry Division, D.S.I.R., unpublished records), and the levels of K^+, Ca^{++}, Mg^{++}, Cl^- and Si^{4+} found in May 1975 are the lowest recorded from thermal springs in this country. The level of Na^+ is also low relative to levels measured in other South Island warm springs (130-360 $g.m^{-3}$, Ellis and Mahon 1964), with the exception of the Otehake River hot spring (Fig. 1) which had a Na^+ concentration of 72.5 $g.m^{-3}$ (Chemistry Division, D.S.I.R., unpublished). Concentrations of dissolved solids are relatively low for a thermal spring (Castenholz 1969).

The upper temperature limit for algal growth in North Island thermal springs is 60°C-65°C, and at these temperatures *Mastigocladus laminosus* or species of *Phormidium* and *Synechococcus* may be found (Brock and Brock 1971). Filamentous bacteria may occur at still higher temperatures, and flexibacteria can form a characteristic orange band beneath the blue-green algal mat at temperatures above about 46°C. White filamentous bacteria were found attached to rocks at the vents in this study but no orange undermats were seen. A large number of cyanophyte "species" have been recorded from thermal waters in New Zealand and elsewhere, but because the systematics of blue-green algae are poorly defined, the true identities of many species are in doubt (Castenholz 1969). Comprehensive lists of algae collected in North Island thermal areas are given by Chapman *et al.* (1957) and Sarma and Chapman (1975), and species identified from some South Island springs are listed by Winterbourn (1973).

The maximum water temperature at the Hurunui springs (54°C) was well below the upper limit for algal growth, and species belonging to the genera *Mastigocladus*, *Phormidium*, *Oscillatoria*, *Synechococcus* and *Lyngbya* were collected there. Representatives of the first four genera also have been collected together at 52°C in a spring outflow channel at Ohinemutu (Brock and Brock (1971). Thick mats of *Lyngbya* have not been recognised in New Zealand before, but have been reported from warm springs in Iceland (Sperling 1975) and Hunter's Hot Springs, Oregon (Castenholz 1973). The Hurunui springs also resemble the Oregon springs, as *Calothrix* is a dominant species at lower temperatures. In Oregon springs, *Oscillatoria terebriformis* is the dominant alga from about 54°C to 46°C, where the algivorous ostracod *Potamocypris* sp. is also present. The lower temperature limit of this alga extends to 35°C-38°C when the ostracod is absent. Below the *Oscillatoria* zone, *Calothrix*, in combination with *Pleurocapsa*, forms a dark, leathery, and often nodular crust (Castenholz 1973: Fig. 19.6). Grazing by *Potamocypris* sp. effectively limits the downstream spread of *O. terebriformis* and permits the *Calothrix-Pleurocapsa* crust to extend its upstream distribution. In the Hurunui springs, where we found little evidence of extensive grazing on the algal mat, *Calothrix* occurred in water temperatures less than 35°C, perhaps because it cannot compete successfully with *Phormidium* spp. at higher temperatures.

Larval and pupal midges (tribe Tanytarsini) were the most abundant animals in the outflow channel. In this respect the fauna resembled that found in a stony stream leading from an alkaline spring beside the Copland River on the west coast of the South Island (Winterbourn 1973). The fauna at the Hurunui springs was more diverse than that of the Copland Springs, however, and this probably reflects both the temperature range of the former and its greater habitat diversity provided by an uneven stony bed, diverse algal mat and large quantities of forest litter which accumulate in the channel. Litter, particularly dead beech (*Nothofagus* spp.) leaves, probably provides an important source of nutrients to the channel, particularly in the form of dissolved organic leachates which can be utilized by the algal and microbial flora, and indirectly by the invertebrate fauna.

The fauna at the highest temperature at which animals were found (47°C) comprised species of Stratiomyidae and Ephydridae. Larval Stratiomyidae have been recorded from North Island thermal waters below 38.5°C and from the Copland Springs at 27°C and 32°C (Winterbourn 1968, 1973). Their presence at water temperatures greater than 40°C extends the known temperature range of this family in New Zealand. Ephydridae are important members of thermal spring faunas in many parts of the world, and the life of most "thermal species" is centred around the bacterial-algal mat which is a source of food for larval and adult insects

(Tuxen 1944, Brock *et al.* 1969). Species of *Ephydrella, Scatella* and *Neoscatella* are known to inhabit thermal waters in New Zealand, but only *Scatella nitidifrons* was found in the present study. It is a widely-distributed species, and has been recorded from North Island springs by Winterbourn (1968) and Brock and Brock (1971). An undetermined species of *Scatella* (probably *S. nitidifrons*) has been found in the South Island at Hanmer Springs and Maruia Springs. The absence of *Ephydrella thermarum*, the most common ephydrid in North Island thermal waters, is difficult to explain especially as it is known to occur at the Copland River springs (Winterbourn 1973). Also notable is the apparent absence of Hydrophilidae (Coleoptera), a family which contains several species common in New Zealand warm springs (Winterbourn 1968, 1973). On the other hand, midges belonging to the subfamilies Orthocladiinae and Tanypodinae were recorded from thermal waters in this country for the first time.

Finally, the presence of two species of Cryptostigmata, one, *Trimalaconothrus novus*, in particularly large numbers, is of interest. Before this study, the only mite known from a New Zealand thermal area (Orakei-Korako) was a species of *Hydrophantes* (suborder Prostigmata) which parasitizes *Ephydrella thermarum* and lays its eggs in the spring outflow channels (Brock and Brock 1971). The Cryptostigmata, in contrast, are non-parasitic and, as they are primarily fungivorous, algivorous or saprophytic (Krantz 1970), may have been feeding on the blue-green algal mat.

ACKNOWLEDGEMENTS

We greatly appreciate the help of Alan Carpenter, David Craib, Jenny Merton, Chris Paulin, and Christine Porter, members of the Biological Society field trip to the springs in May 1975. The assistance of Ranger L.G. Morris, Mr J.W. Levy (Conservator of Forests, Canterbury), and other members of the New Zealand Forest Service was most welcome. Mr G. Warren and Dr A.T. Dobson commented on parts of the manuscript. We thank Dr G.W. Ramsay for the identification of mites, Dr A.T. Dobson for the identification of some plants, and Mr D.J. Hogan, Chemistry Division, D.S.I.R., Christchurch, for providing results of water analyses.

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